

## **Best Practices for Energy Efficient Cleanrooms Efficient HVAC Systems: Variable-Speed-Drive Chillers**

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**Best Practice for Energy Efficient Cleanrooms**  
**Efficient HVAC Water Systems: Variable-Speed-Drive Chillers**  
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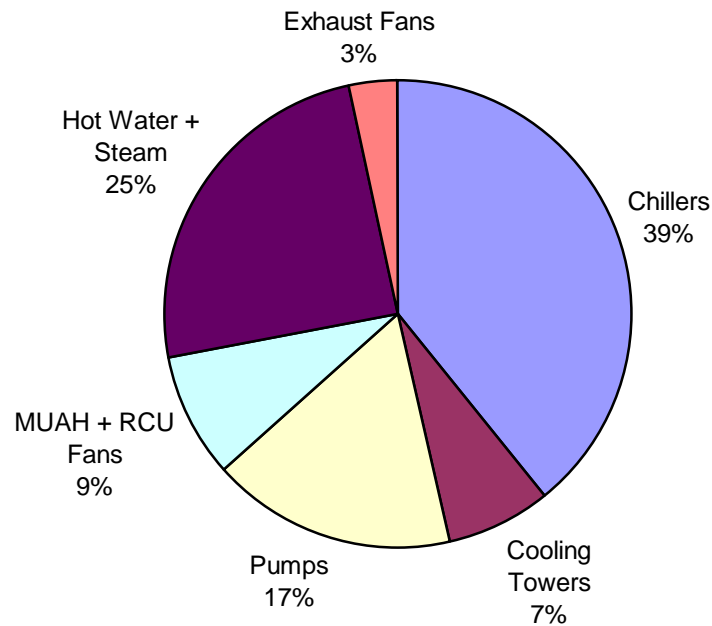
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# HVAC Water Systems

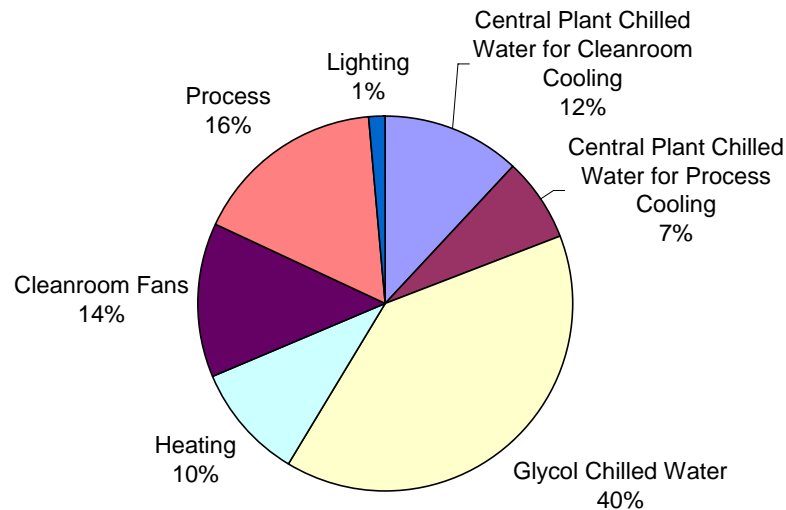
## Variable-Speed-Drive Chillers

### Summary

Cleanroom energy benchmarking data shows that there is a variety of chiller plant designs and operating efficiency for cleanroom facilities. Chiller plants usually serve cleanroom facility and adjacent spaces simultaneously and use significant energy and water. The efficiency level of the overall chiller plant is influenced by the efficiency of individual components and subsystems in the plant. Major components include chillers, water pumps, and cooling tower or condenser fans. Figure 1 and Figure 2 show chiller energy end-use in typical semiconductor cleanroom facilities. In both cases, the portion of chiller energy usage was significant. It is, therefore, important to design, select, operate, and control chillers to achieve high efficiency and to lower life-cycle costs for cleanrooms and their adjacent spaces.



**Figure 1. Benchmarked HVAC energy usages in a semiconductor cleanroom facility**



**Figure 2. Benchmarked cleanroom energy usages in a semiconductor cleanroom facility**

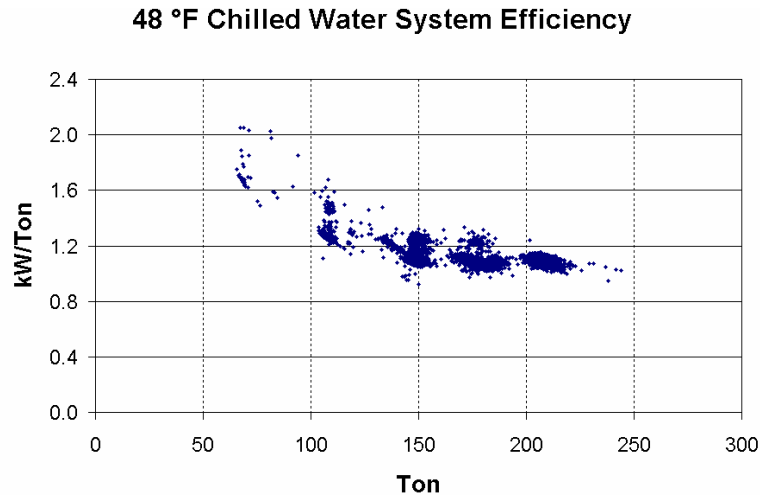
## Principles

The type of chiller selected and its operation normally has the most significant impact on overall chiller plant efficiency and energy use in the facility. Normally, water-cooled chillers and those with evaporative condensers are more efficient than their air-cooled counterparts. That is, an air-cooled chiller plant is less efficient than a combined water-cooled chiller and cooling tower or evaporative condenser system.

It's important to note that chillers operating at partial load conditions usually correspond to lower energy efficiency, as illustrated in Figure 3. This was benchmarked in one of the cleanroom facilities.

At part-load conditions, the pumps and heat rejection device often operated at constant speed, thus increasing their fractional contribution to reducing the overall efficiency (kW/ton). Installing a variable-speed drive (VSD) may increase the operating chiller part-load efficiency.

In addition to energy savings from installing VSDs, there are other potential benefits such as capital savings, lower sound level, reduced wear of compressors, better electrical protection, and improved power factors and reduced harmonics.



**Figure 3. Chiller efficiency vs. cooling load**

#### Best practice approaches

Chiller efficiency is affected by many factors, including size, components such as chiller motor efficiency, temperature delta (or ‘lift’) of chilled water, sizing of the evaporator and condenser heat exchangers, cooling loads, and condensing temperatures. While the energy efficiency of individual components influences the overall chiller plant efficiency, how the equipment is controlled and operated also largely affects the actual chiller system efficiency and therefore its energy usage.

Providing variable-speed drives for chillers typically improves their operating efficiency, because the chiller operation with a variable-speed drive is generally more efficient at part loads and more responsive to varying loads than constant-speed drive chillers with their throttling or staging load controls. Electric power input can be reduced by incorporating a variable-speed drive in a chiller when the chiller is operating at a partial load, e.g., half load or less. Best practice requires that relevant efficiency measures be first taken to reduce the load. Based upon such a new load, the sizing and life-cycle cost benefit of a variable-speed drive can then be best evaluated and implemented when it’s feasible. Chiller efficiencies over the range of operating conditions, with and without VSDs, are available from the chiller manufacturers to facilitate the analysis.



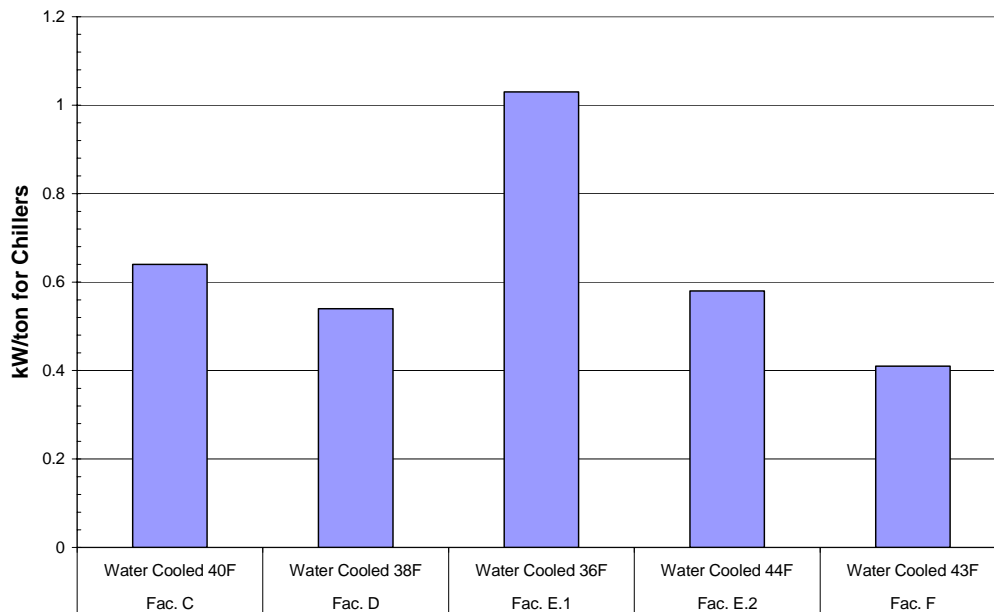
**Figure 4. Chiller with a VSD in the large rectangular enclosure**

### Case studies

In general, measures such as chilled water temperature reset, providing VSD and improving control will improve the operating efficiency of chillers. Chillers operate more efficiently when the lift (the difference in temperature between the hot and cold refrigerant) is minimized, and when equipped with variable-speed drives.

Often, a chilled water plant may serve various loads that call for different chilled water temperatures. In one case study, the chilled water temperature for cleanroom process required was 60°F, chilled water temperature for the re-circulation air handlers and makeup air handlers was 55°F, and chilled water for dehumidification in the makeup air handlers and for the air handlers in other buildings served by the plant was 38°F. Chiller efficiency is directly affected not only by chilled water supply temperature, load, and chiller type, but also system controls such as the use of a VSD.

Figure 5 shows the variations in water-cooled chiller efficiency for a group of cleanroom facilities. The chilled water temperatures ranged from 36 to 40°F, while the chiller efficiency ranged from 0.4 to 1.2 kW per ton. The best practice water-cooled chiller efficiency was 0.4 kW/ton based upon the benchmarked data, for the chillers producing 43°F chilled water. Opportunities exist to improve operating chiller efficiency as illustrated in Figure 5. For example, providing VSD option for water chillers for the facilities (e.g., Facility C) shown in Figure 5 would further improve operation efficiency of the chillers because most of the chillers benchmarked were commonly operating under partial load conditions.



**Figure 5. Water-cooled chiller efficiency**

#### Related best practice

- ◆ Right sizing
- ◆ Cooling tower and condenser optimization
- ◆ Control of chilled water systems
- ◆ Variable-speed drive water pumping
- ◆ Free cooling
- ◆ Dual temperature cooling loops

#### References

- 1) <http://hightech.lbl.gov>

#### Resources

- Energy Design Resources, Design Brief: Chiller Plant Efficiency, <http://www.energydesignresources.com/resource/24/>
- ASHRAE handbook – HVAC systems and equipments.

- PG&E's CoolTools, <http://www.hvacexchange.com/cooltools/>